Measuring and Monitoring Success in Compressing Morbidity

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The Compression of Morbidity paradigm, introduced in 1980, maintains that if the average age at first infirmity, disability, or other morbidity is postponed and if this postponement is greater than increases in life expectancy, then cumulative lifetime morbidity will decrease—compressed between a later onset and the time of death. The National Long-Term Care Survey, the National Health Interview Survey, and other data now document declining disability trends beginning in 1982 and accelerating more recently. The decline is about 2% per year, contrasted with a decline in mortality rates of about 1% per year, thereby documenting compression of morbidity in the United States at the population level. Longitudinal studies now link good health risk status with long-term reductions in cumulative lifetime disability; persons with few behavioral health risks have only one-fourth the disability of those who have more risk factors, and the onset of disability is postponed from 7 to 12 years, far more than any increases in longevity in the groups. Randomized, controlled trials of health enhancement programs in elderly populations show reduction in health risks, improved health status, and decreased medical care utilization. Health policy initiatives now being undertaken have promise of increasing and consolidating health gains for the elderly.

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The Compression of Morbidity paradigm, which was presented as an hypothesis in 1980 (1), noted that most illness was chronic and occurred in later life and postulated that the lifetime burden of illness could be reduced if the onset of chronic illness could be postponed and if this postponement could be greater than increases in life expectancy. **Figure 1** illustrates this concept. Estimated present lifetime morbidity is portrayed with three possible future scenarios: life extension, shift-to-the-right, and compression of morbidity. The lines represent the length of life, and the shaded triangles depict lifetime morbidity. Two arrows are shown for each scenario: The left arrow represents the median age at onset of chronic morbidity and the right arrow represents the median age at death. Alternative health futures are determined by the relative movement of these arrows over time. If the arrows separate, lifetime morbidity increases, and if they come closer, morbidity is compressed. In each scenario, some extension of life expectancy is envisioned. The illustrative use of age 55 years as the present age of onset of chronic morbidity is drawn from our data showing this to be the median age of detectable chronic disability (2).

In 1980, most demographers and health policy workers believed that the life extension scenario was occurring and was the most likely, and most unfortunate, future for health. As medical progress increasingly prolonged life, those extra months and years would be spent in poorer health. The process was termed the "failure of success" (3).

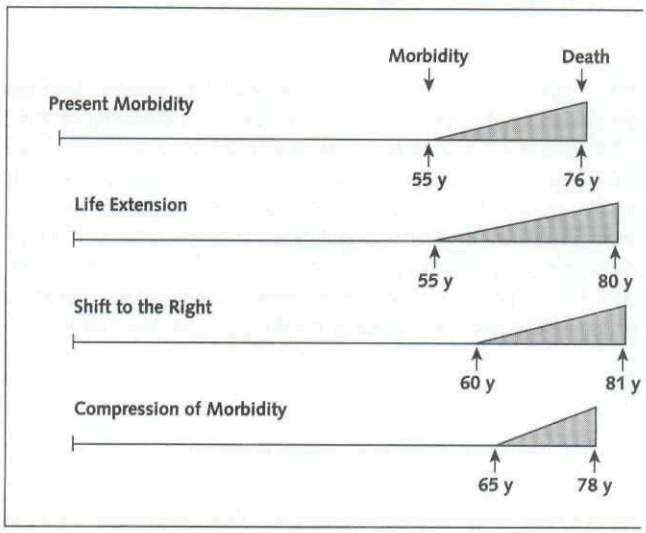
The Compression of Morbidity represented a positive concept, with the ideal of a long life with a relatively short period of terminal decline. Initially, the concept was sometimes portrayed as naively optimistic and, perhaps, a threat to the preparation required to care for ever-larger elderly populations (4, 5). A problem in 1980 was the lack of data on trends in morbidity; such data would have required serial population surveys with similar methods, and these were not available. There was not even agreement on the definition of "morbidity," nor is there now. It seemed reasonable in 1980 to postulate that lifetime morbidity had been rising with the emergence of chronic illnesses, but it could be argued that this period was ending with declining incidences of major chronic illnesses, such as cardiovascular disease (1).

The Compression paradigm focuses attention on the quality of life over its quantity and considers morbidity as a lifetime cumulative area-under-the-curve concept rather than just a cross-sectional particular point of time, such as a specific age. It suggests that the national burden of illness may be reduced by postponing the onset of infirmity. Thus, the national illness burden that is increasing because of the growing number of elderly persons in the population may be offset, at least in part, by a lower average illness burden for the individual, with positive consequences for the stability of the health care system.

This paper draws on recent data from national surveys, observational longitudinal studies, and randomized, controlled trials to bring together the current evidence for morbidity compression in the United States and to outline the research agenda for the continued monitoring of trends in morbidity and disability.

Given appropriate data, the Compression hypothesis can be tested by using age-specific disability rates or cumulative lifetime disability as surrogates for the less easily quantitated morbidity rates. Trends in age-specific disability can then be compared with trends in age-specific mortality, and trends toward a postponed point of incident disability can be compared with trends toward a postponed age at death. If age-specific disability declines faster than age-specific mortality, then compression is established. Even better, if given serial cohorts of longitudinal data, trends in cumulative lifetime disability could be assessed. In addition, if disability could be postponed by specific interventions (such as exercise, weight control, total joint replacement, influenza vaccination, or smoking cessation) by more than projected increases in the length of life from these interventions, then strategies for reduction in the national burden of illness by dissemination of these interventions would become possible.

Figure 1. **Possible scenarios for future morbidity and longevity.**



Present lifetime morbidity, portrayed as the shaded area, is contrasted with three possible future scenarios.

Trends in Mortality

Since morbidity compression depends on the relative trends in morbidity and mortality, trends in life expectancy must be examined. From 1980 to 1998, life expectancy (U.S. data; both sexes combined) rose at a rate of 0.150 year per year, for an increase of 2.7 years, to 76.6 years, somewhat slower than in the two previous decades (6). The more relevant number, however, is life expectancy from age 65 because it excludes early-life mortality. Life expectancy from age 65 rose at a rate of only 0.066 year per year, for an increase of 1.2 years over 18 years, to a life expectancy of 82.7 years; this is a slightly lower rate of increase than in previous decades. From age 85, life expectancy rose by 0.017 year per year for an increase of 0.3 years or only about 4 months over 18 years. If present trends continue, gains in life expectancy after 65 years of age will remain modest. Because of larger birth cohorts and an increasing proportion of persons surviving to age 65, however, the number of elderly persons will increase markedly.

Present trends, however, will not continue indefinitely. Barring discovery and dissemination of a breakthrough in understanding of the basic science of aging, the rates of increases will continue to slow. Constant decreases in mortality rates, about 1% per year, yield diminishing increases in terms of life expectancy over time because of the mathematical relationship between the two statistics; the absolute value of the mortality rate change decreases over time (7). This can be seen with the "point of paradox," in which life expectancy from birth, rising more rapidly, exceeds life expectancy from age 65 years, rising more slowly, after an intersection point at a life expectancy of 87.8 years in the year 2076. Because this is not possible, present trends cannot continue indefinitely.

Trends in Morbidity

Over the past two decades, it is possible that a great natural experiment occurred in which preventive measures, which are most relevant to postponement of morbidity, had been broadly implemented. On a national basis, there could have been massive reductions in health risk factors, such as cigarette smoking, obesity, and sedentary lifestyle. Then, with emerging data on trends in disability, particularly from the National Long-Term Care Survey (NLTCS) (8) and the National Health Interview Survey (NHIS) (9), we could assess the benefits from these changes against changes in mortality. Unfortunately, although smoking did decrease significantly, the prevalence and amount of obesity increased, and a trend toward more sedentary lifestyles continued. Over the last two decades, therefore, lifestyle changes probably did not play a major role in compression of morbidity.

Nevertheless, compression of morbidity is occurring, and at a relatively rapid rate. In the NLTCS data (**Table**), disability in persons older than 65 years of age decreased from 26.2% to 19.7% from 1982 to 1999, a decrease of approximately 2% per year and substantially greater than the decreases in mortality rates over this period, which declined at about 1% per year (10). The decline was seen both in activities of daily living disability and instrumental, more complex activities of daily living. It has been argued that a decline in age-specific disability of 1.5% per year would be sufficient to maintain the solvency of Medicare for at least 70 years (11). Moreover, the declines in disability in the NLTCS accelerated in the past 5 years of observation and began to be seen in minority as well as white subpopulations (8). Data from the NHIS from 1982 to 1996 show strikingly similar declines in disability, again with an accelerated rate of decline in more recent years (9).

Recently, Freedman and colleagues (12) performed a systematic review of 16 studies of trends in disability and found them consistent in the finding of declining disability trends. Thus, the literature, although of uneven quality, shows consensus. Only the NLTCS data had a sample of

Table. **Long-Term Trends in Disability***

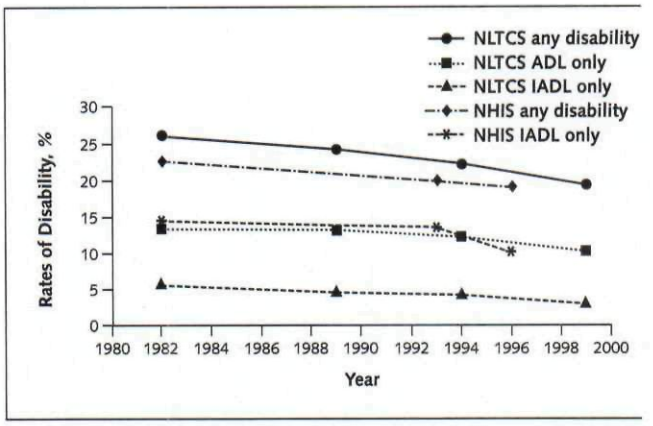
Disability and Housing	1982	1984	1989	1994	1999
	← % →				
Total disabled	26.2	26.2	24.4	22.5	19.7
Mild disability (IADL)	5.7	6.2	4.8	4.4	3.2
Moderate disability	6.9	7.0	6.7	6.1	6.0
Severe disability	3.0	3.1	3.7	3.4	3.5
Very severe disability	3.7	3.4	3.0	3.0	2.9
Institutionalized	6.8	6.6	6.1	5.7	4.2
Assisted living	0.0	0.0	0.0	0.0	2.3
Nursing home	6.2	5.9	5.8	5.4	3.4

* IADL = instrumental activities of daily living. Adapted with permission from the National Long-Term Care Survey (Manton KG, Gu X. Changes in the prevalence of chronic disability in the United States black and nonblack population above age 65 from 1982 to 1999. Proc Natl Acad Sci USA. 2001;98:6354-9. Copyright (2001) National Academy of Sciences [8]).

all Medicare-eligible persons, both institutionalized and not; covered a sufficient time period (1982 to 1999); and had well-defined disability measures. This is the single best study (**Figure 2**) (13).

The reasons for the decline in disability seem to be multifactorial, with no single identifiable cause. There may have been contributions from reductions in cigarette smoking; medical advances, such as better treatment of hypertension, diabetes, coronary artery disease, and rheumatoid arthritis; total joint replacements; and medical preventive measures, such as colon cancer screening, influenza and pneumococcal vaccines, and cardiac-dose aspirin (10). It might be that rising expectations for healthier aging became self-fulfilling, perhaps through a mechanism of perceived self-efficacy (14). The association between level of education and health is strong, and self-efficacy might at least partly explain this association; education levels in the elderly rose substantially over the past two decades (15). Social factors do not seem to have played a role; access to care has not improved, and access to prescription drugs may have become more difficult (10). Whatever the reasons, compression of morbidity is currently occurring at the population level in the United States.

Figure 2. **Recent trends in disability among older Americans.**



Disability rates decline at about 2% per year; the declines accelerate in the most recent time period in the National Long-Term Care Survey (*NLTCS*) and the National Health Interview Survey (*NHIS*). Declines are in both activities of daily living (*ADL*) and instrumental activities of daily living (*IADL*) in the NLTCS. In the NHIS, declines were similar for IADL but not significantly changed for ADL.

Health Risks and Lifetime Disability

Longitudinal studies of the relationships of lifestyle risk factors to subsequent disability levels in advantaged elderly populations provide an additional perspective on the magnitude of postponement of disability that might result from lifestyle changes. Studies of populations with good education levels, relative affluence, and good access to medical care are important because, otherwise, socioeconomic class is a strong confounding variable. An important issue is whether lifestyle change can provide improvement "at the margin," when medical and social support is already near optimal. Our group is conducting two such ongoing studies: a study of University of Pennsylvania alumni since 1986 (average age in 1986, 68 years) and a study of fitness club members and community controls begun in 1984 (average age in 1984, 58 years).

Effects of good health habits on subsequent disability were extremely large. In the alumni study, after adjustment for a wide range of possible confounding variables, the cumulative lifetime disability since 1986 was four times as great in those who smoked, were obese, and did not exercise as in those who were lean, exercised, and did not smoke. The onset of initial disability was postponed by 7.75 years in the best one third compared with the worst one third (16). Moreover, in those 418 who had died and whose true lifetime disability could be computed, those with low health risks had lower disability levels at each year before death, although there was a slow increase over time. Persons with higher health risks had more disability throughout observation and also a surge to rather high disability levels in the 2 years before death (17). In the Fitness Club study, with use of intention-to-treat analyses and after adjustment for covariates, the initial exercise club cohort had postponement of mild disability, as measured by the Health Assessment Questionnaire, by 12.8 years as compared with more sedentary controls (18). The lowest Health Assessment Questionnaire disability level detectable in a person is 0.125 on a 0 to 3 scale. Thus, average numbers lower than this indicate the presence of a number of persons with no detectable disability and a score of 0 (**Figure 3**). These postponements of disability far exceed any increases in life expectancy.

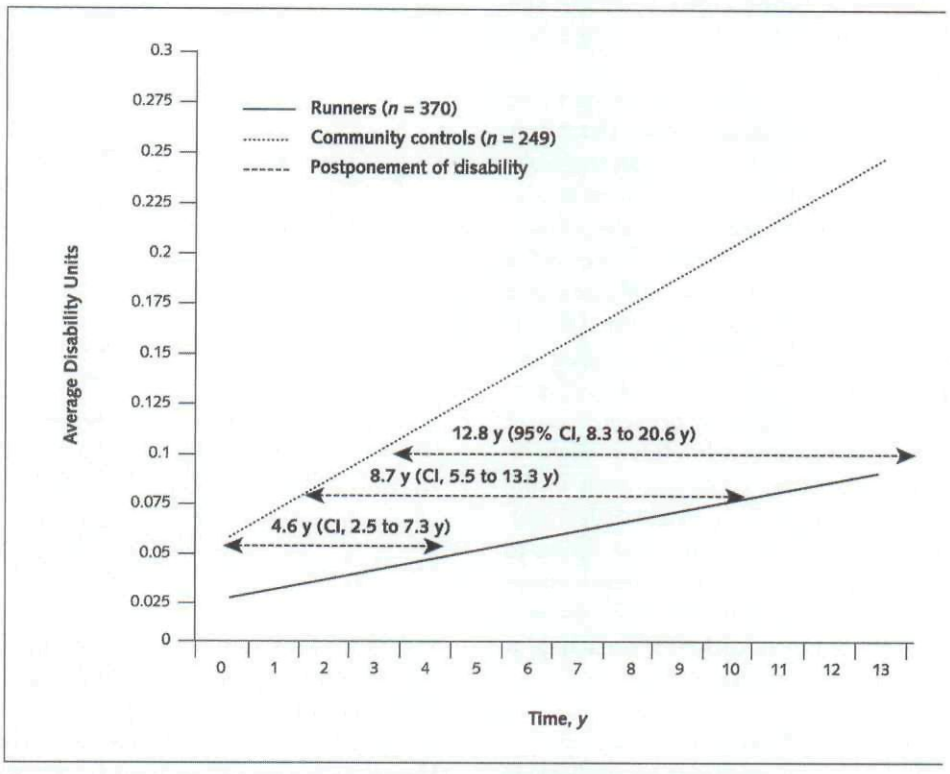
Health Enhancement Interventions

A final metric is examination of the effects of interventions. Is it possible to intervene in elderly populations, improve risk factor profiles, and observe improved health and reduced medical care costs? Or would such intervention be "too little, too late"? Large randomized, controlled trials of health promotion programs in the elderly or retirees (19, 20), in particular those using complex "tailored print interventions" very specific to the participant, have documented health improvement. Risk reductions have approximated 10% per year of intervention, and improved self-reported health, decreased disability and pain (21), and reduction in medical care utilization, both by self-report and analysis of claims, of at least 10% per year have been reported (22, 23).

Health Policy Initiatives

Current data on trends in morbidity and mortality suggest that we must be doing something right. The surprise is that this seems to have occurred even though we have not systematically implemented what is possibly the most promising approach, postponing disability through primary prevention, into the health care system. We now

Figure 3. **Regression of disability on time period (using bootstrap methods).**



Development of disability over a 13-year period from an average age of 58 years in runner's club and community control groups. Linear regression lines are adjusted for covariates and document postponement of disability in the fitness club group compared with controls, with differences increasing over time.

have serial data documenting health improvement and monitoring systems in place to observe future trends. We have solid underlying theory, proof of concept by longitudinal epidemiologic studies, and proven interventions that can be applied broadly. While health risk improvement is the most promising single approach to accelerating compression of morbidity, it will also be important for us to focus additional efforts on reducing disability from the nonfatal diseases. The most prevalent conditions of later life, such as osteoarthritis, rheumatoid arthritis, depression, isolation, and Alzheimer disease, have relatively little effect on mortality yet cause an immense amount of morbidity. Progress against disability from these conditions is a particularly leveraged way to accelerate morbidity compression.

Arguably, our greatest national health problem is the health of the elderly, and our greatest economic problem is also the health of this population. There is an urgency to find and implement solutions (24, 25). In 2001, RAND was commissioned by Medicare to perform an evidence-based review of health promotion programs for the elderly to determine whether demonstration programs should be performed, with a goal of providing effective prevention programs to improve health of the elderly as a Medicare benefit. The review was positive (22), and a design project has been funded.

A consortium of concerned institutions and individuals has formed to actively seek legislative action (available at www.HealthPromotionAdvocates.org), and a Sense of the Congress Resolution on Building Health Promotion into the National Agenda has attracted strong support in both the Senate and the House of Representatives. Healthy Senior bills have been presented in both houses of Congress. Legislation is being developed to request federal support to develop the basic and applied science of health promotion, and subsequent legislation will seek support for programs for the most vulnerable segments of our population. This is unprecedented activity and a remarkable opportunity for major change and for major health improvement.

The Compression of Morbidity research agenda includes 1) monitoring of disability trends through the national survey programs, with addition of more quantitative disability measures to the instruments and inclusion of quality-of-life measures, 2) attempting to more precisely define the causes behind the trends, possibly using econometric techniques, and 3) performing systematic studies of specific primary prevention interventions, with the goal of identifying population-based approaches to compression of morbidity that are most effective and most cost-efficient.

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